Application Note
#4
Harmonic Content

In a previous application note (Application Note #2, Identifying a Resonance) data showed excitation by N1 harmonic content. A reader has asked, "Where does the harmonic content come from?" Well, the simple answer is that it comes from the fundamental; the harmonic content is a distortion of the one/rev signal. Now this is where everybody get excited needlessly. The immediate reaction to this statement is that distortion is bad. Well, it's not. It's just a fact of life that is accounted for and we all live with.

There are a lot of masses and dimensions involved in an gas turbine engine. If the structure was a simple single surface (plane) with a single shaft that was supported at it's critical points then a pure 1/rev signal would be highly probable (notice I didn't say "certain"). The child's toy gyroscope is a perfect example of such a simple structure. If you played with one of these toys when you were younger, you will remember that considerable force was needed to move the end points with the gyroscope spinning. And further, once the end point was in a certain position it tried very hard to stay there. We were all told that this was because of centrifugal force. But, let me tell you, if the wheel was out of balance things would have been very different.

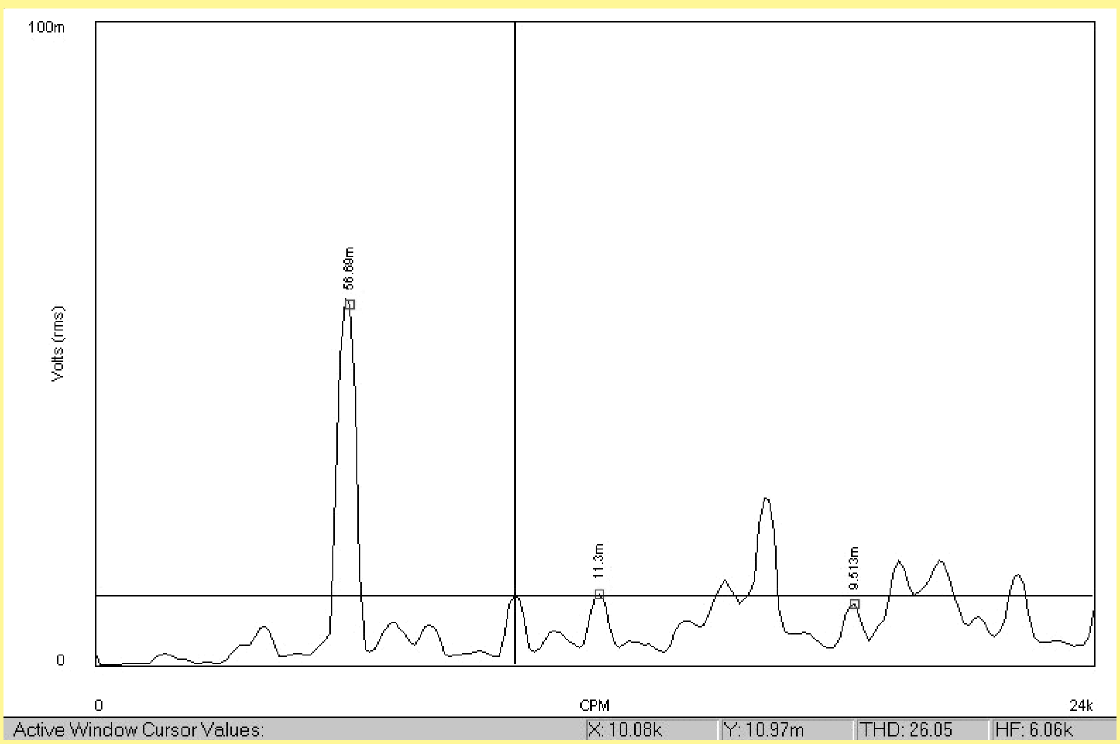


Figure 1

The various masses with their various dimensions within an gas turbine engine work to exert forces in different directions simultaneously. The larger the mass or the larger the dimension the more significant the forces involved. The bearings in an engine are placed not only for mechanical reasons, but they are also the constraints placed upon these forces. When a fan or an LPT goes out of balance all of a sudden these internal bearings are suddenly in the wrong places to contain the forces. They continue to try to constrain the irregular motion but, what they really do is contaminate the 1/rev vibration.

The plot shown in Figure 1 on the previous page is from the same data that was used in Identifying a Resonance. It is taken from a section of the engine run where the imbalance of the fan had not yet started to exert its forces. Take note of the active cursor line, paying particular attention to the number for THD. THD is the acronym for Total Harmonic Distortion. THD is expressed as a percentage. Or, put another way, how much energy of the fundamental is actually present in the harmonic content in the form of distortion? The lower the THD number the better everything is. Here the number, 26.05%, is symptomatic of a problem, even though the amplitude of the signals themselves are comparable to the amplitude of the N2 speed signal identified by the cross hair cursor. The amplitude of N2 is 10.97mVolts whereas the amplitudes of the N1 second harmonic is 11.03mVolts and the third is 9.51mVolts.

The comparison graph in Figure 2, shows data which is a little tricky now. We want to measure the N1 speed signal at a point where the physical constraints of the structure are starting to take place, but simultaneously we have to select a point where the harmonics are not in the area of resonance identified in the past application note.

The amplitude of the 1/fan has continued to climb. The amplitude, read as 127.5mVolts, equates to a level that is above the vibration limit for the engine being tested. The limit would equate to a level of approximately 100mVolts.

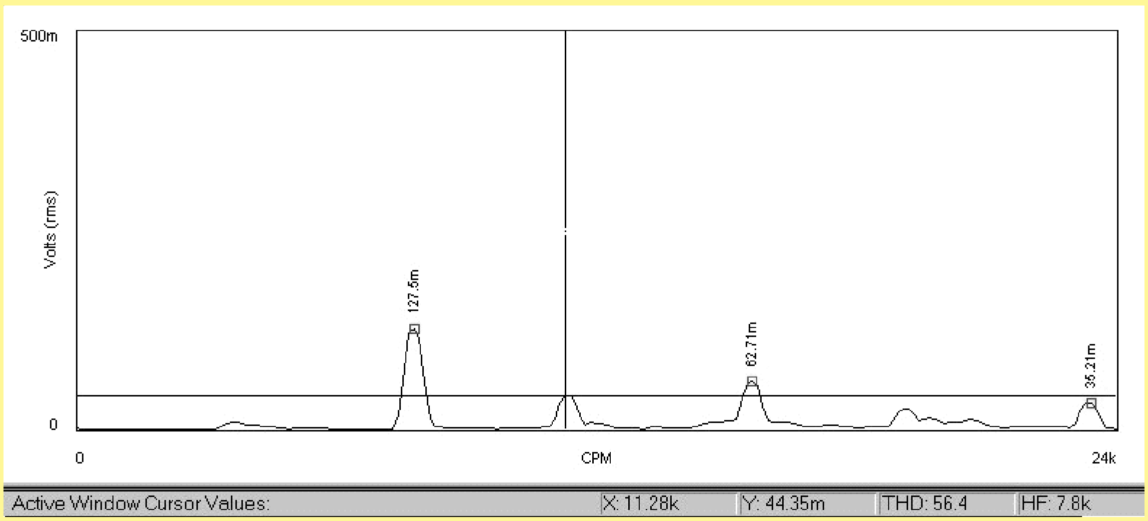
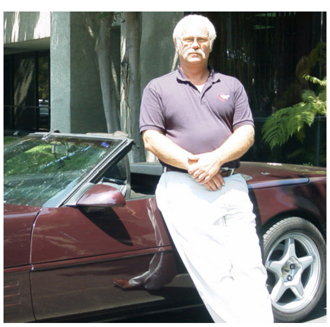


Figure 2

Taking this into consideration, one could safely assume that the motion due to imbalance of the N1 rotational components is starting to become restrained more than would normally be required by a smooth running engine. Note the THD number. It is now a significant at 56.4%, a second indication that things are not as they should be.

It is important to remember that one does not need couplings or bent shafts, alignment or other classic contributors to have harmonic content. Harmonic content can be very evident even on the cleanest of systems. A propulsion engineer familiar with vibration sources will keep this factor in consideration and understand the physical characteristics of the engine so the right corrective measures can be taken or correct decisions can be made with regards to engine health.



For more information on the analysis capability of the CV610C or other aircraft engine measurement systems contact Cognitive Vision.

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